Lecture 5

Multicomponent Phase Behavior in Reservoirs

Lecture Road Map

Lecture 4 – Binary phases and Retrograde Behavior

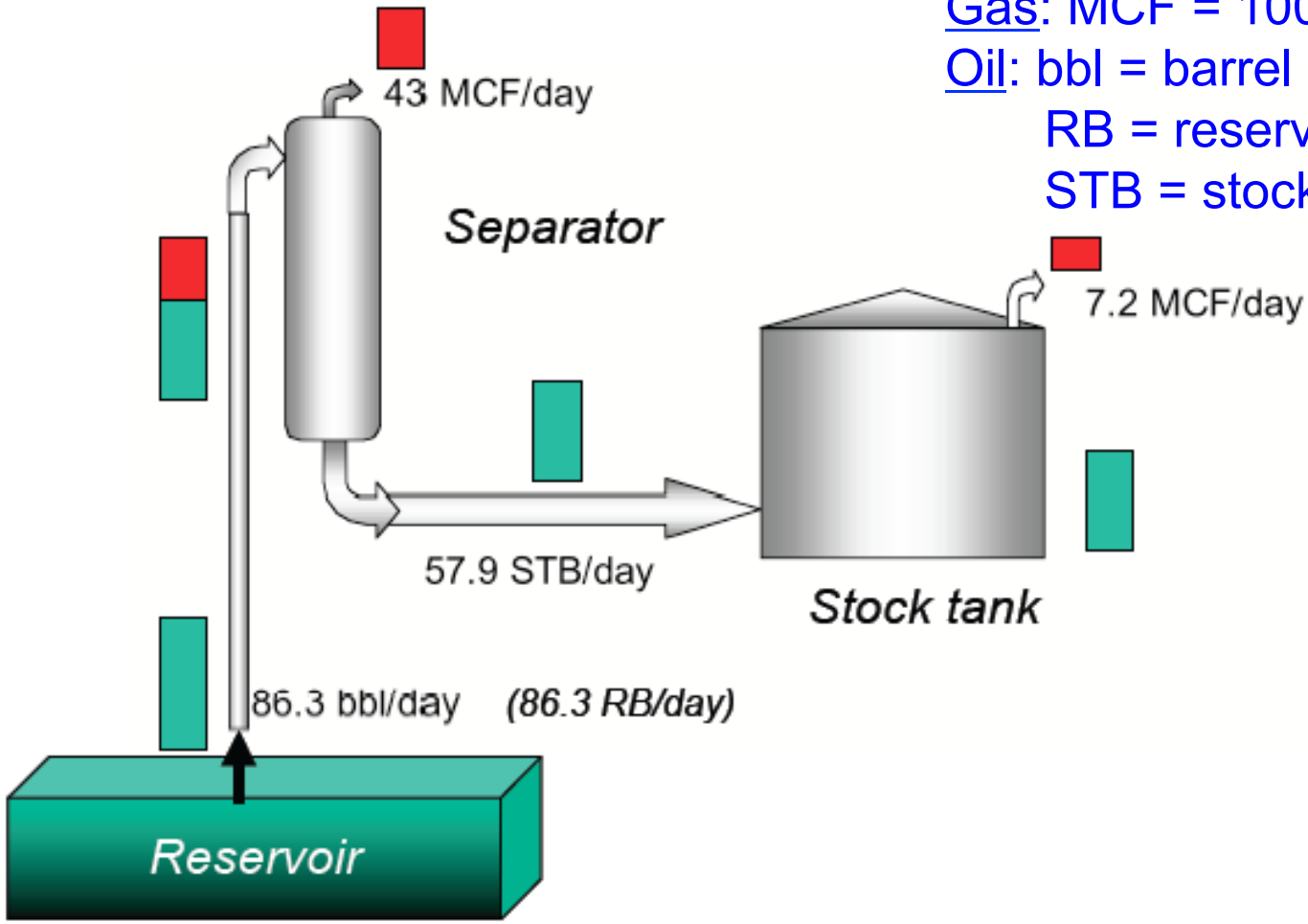
Which leads to Lecture 5 on:

- Formation volume factors
- Solution gas-to-oil ratio

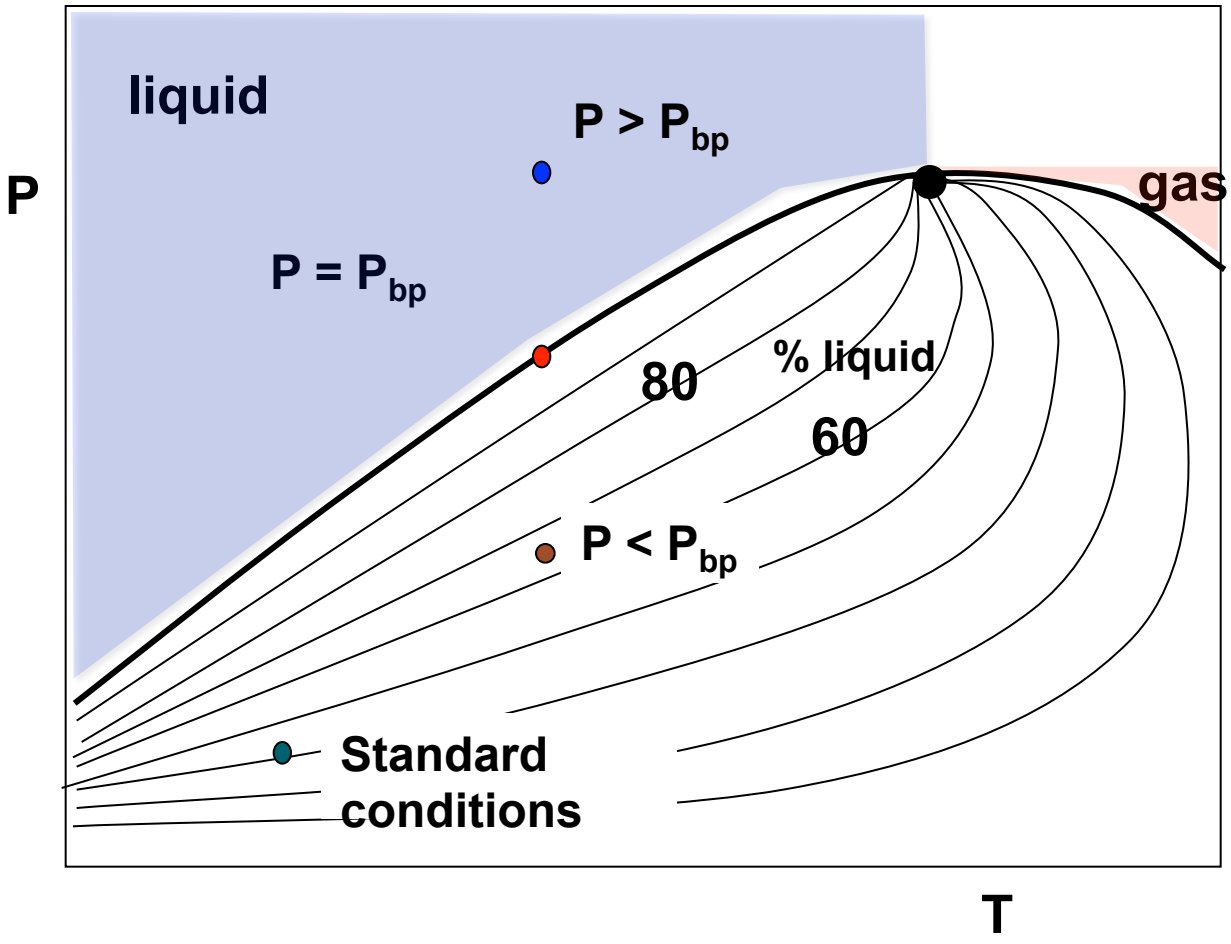
And, finally, application to varying reservoirs in Lec. 6.

Definitions of Barrels

Gas: MCF = 1000 ft^3 gas
Oil: bbl = barrel = 42 gallons
RB = reservoir barrels
STB = stock tank barrels



PT Diagram



1. Liquid
2. BP
3. Mixture

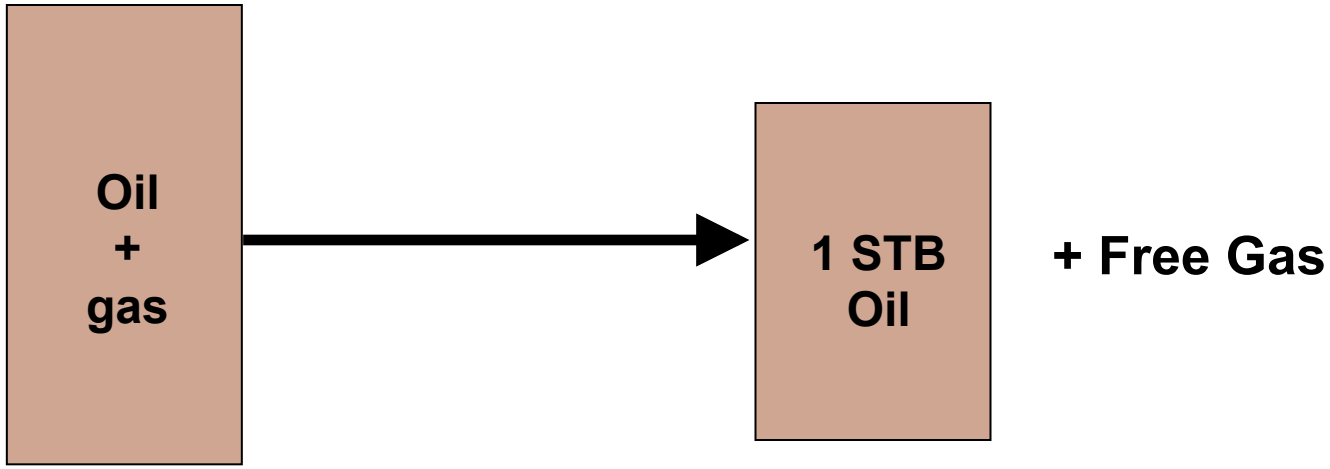
Standard Conditions = 20 ºC and atmospheric P

Oil Formation Volume Factor

Scenario 1: $P > P_b$

$$B_o = \frac{\text{Reservoir Barrels}}{\text{Stock Tank Barrels}}$$

$$B_o = \frac{\text{Volume of Oil + Dissolved Gas @ RC}}{\text{Volume of Oil Entering Stock Barrel Tank @ SC}}$$



V_1 @ RC

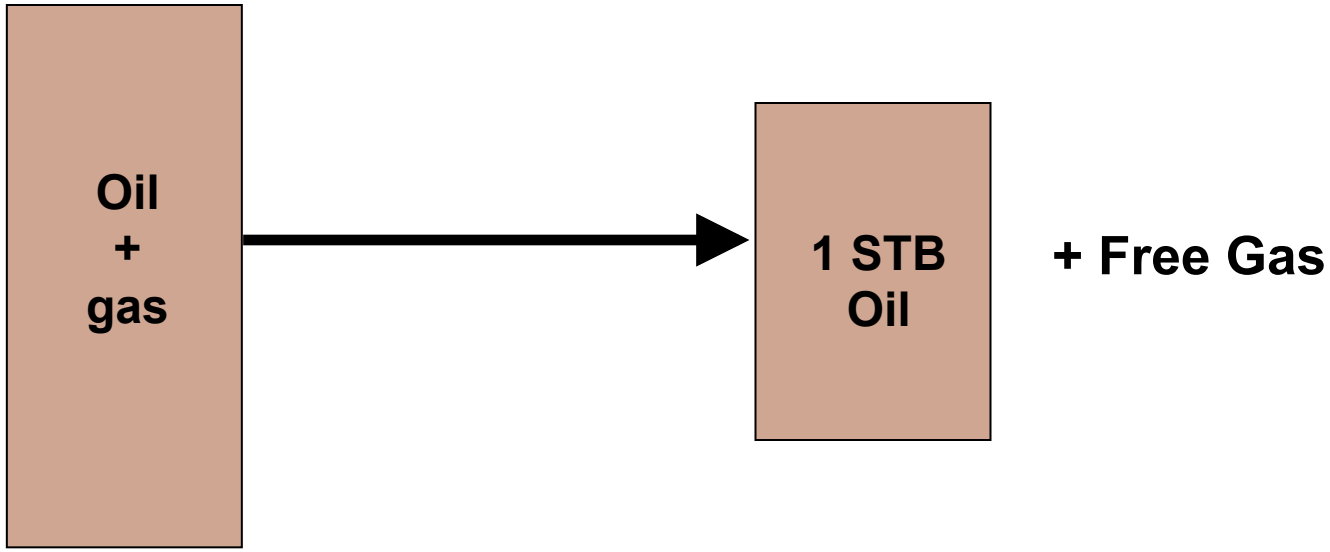
V_0 @ SC

Oil Formation Volume Factor

Scenario 2: $P = P_b$

$$B_o = \frac{\text{Reservoir Barrels}}{\text{Stock Tank Barrels}}$$

$$B_o = \frac{\text{Volume of Oil + Dissolved Gas @ RC}}{\text{Volume of Oil Entering Stock Barrel Tank @ SC}}$$

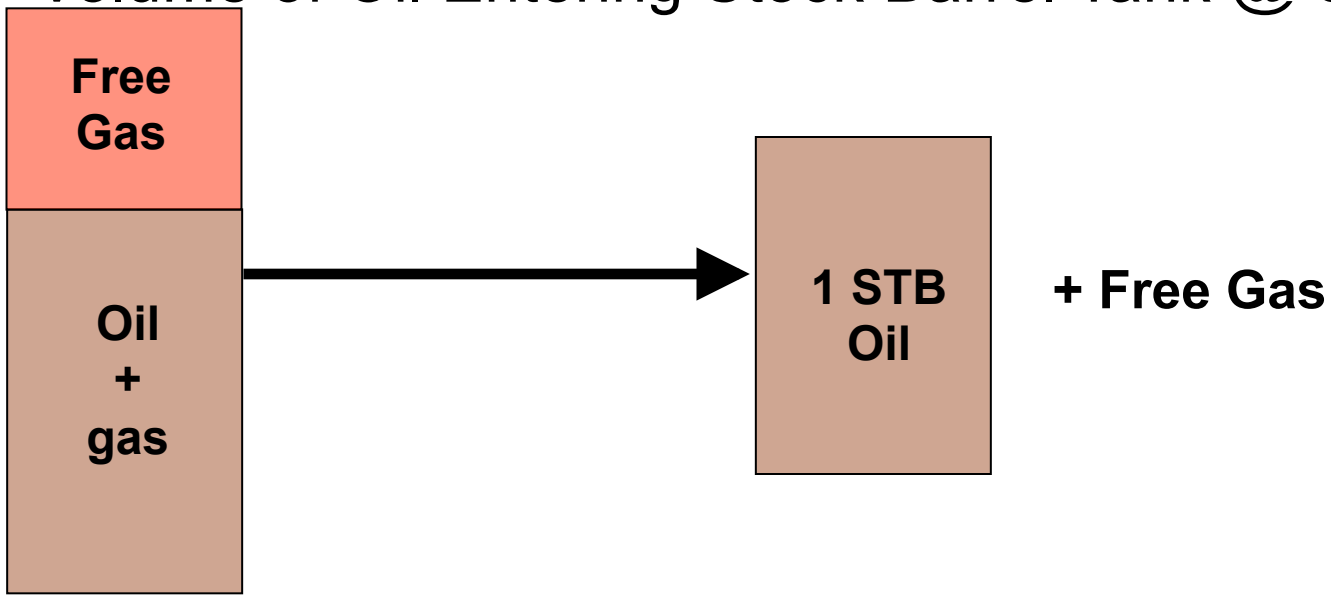


Oil Formation Volume Factor

Scenario 3: $P < P_b$

$$B_o = \frac{\text{Reservoir Barrels}}{\text{Stock Tank Barrels}}$$

$$B_o = \frac{\text{Volume of Oil + Dissolved Gas @ RC}}{\text{Volume of Oil Entering Stock Barrel Tank @ SC}}$$



Oil Formation Volume Factor, B_o

Information B_o provides:

How much reservoir oil (oil and dissolved gas) does it take to get one STB of oil at the surface?

B_o depends on the reservoir pressure:

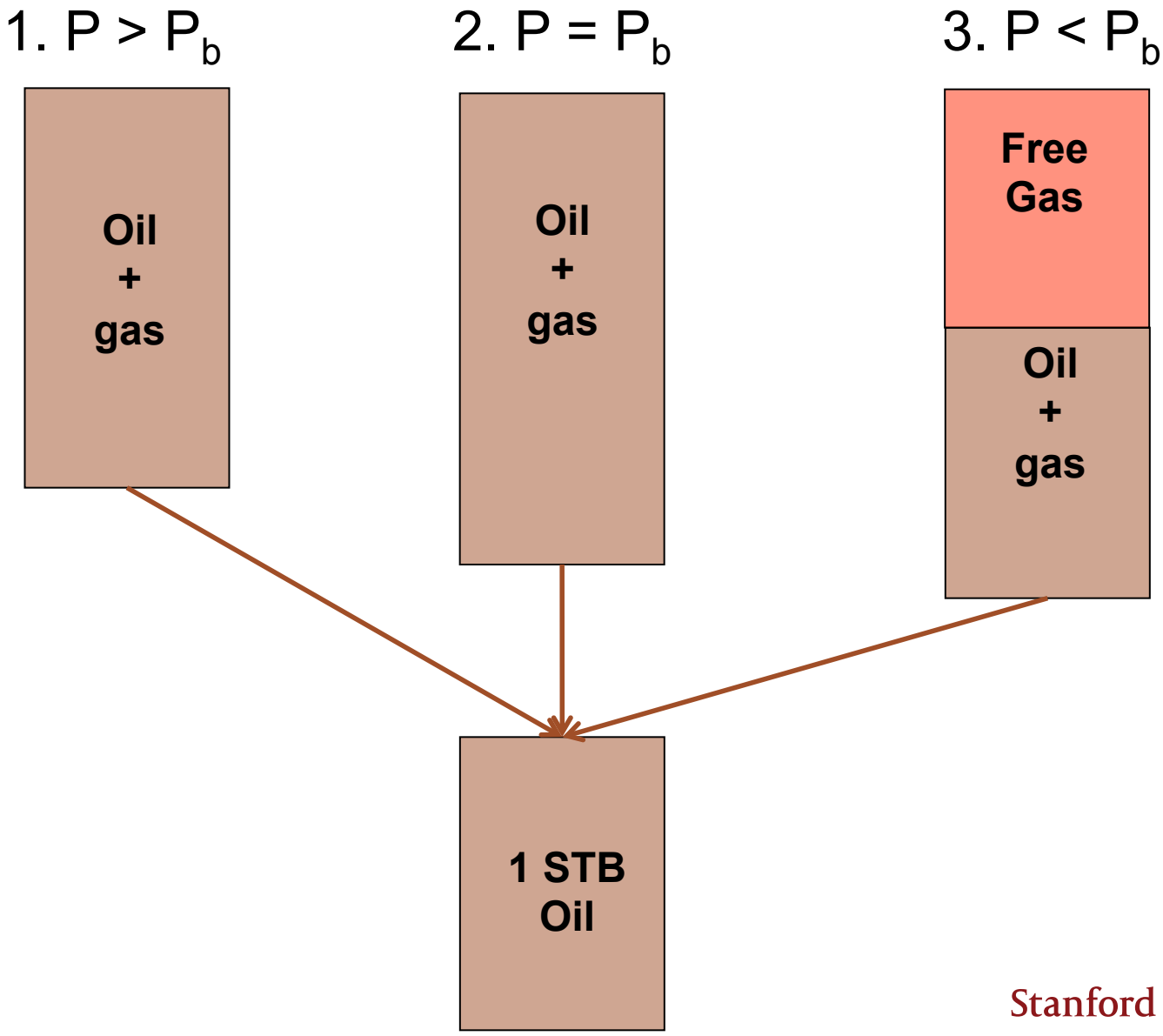
- **If $P < P_{bp}$ much of the gas component* is free in the reservoir, but some gas is dissolved in the oil**
- **If $P = P_{bp,}$ the maximum amount of gas possible is dissolved in the oil**
- **If $P > P_b$ the maximum amount of gas possible is dissolved in the oil and the oil is compressed**

gas component refers to species that are gaseous at STP

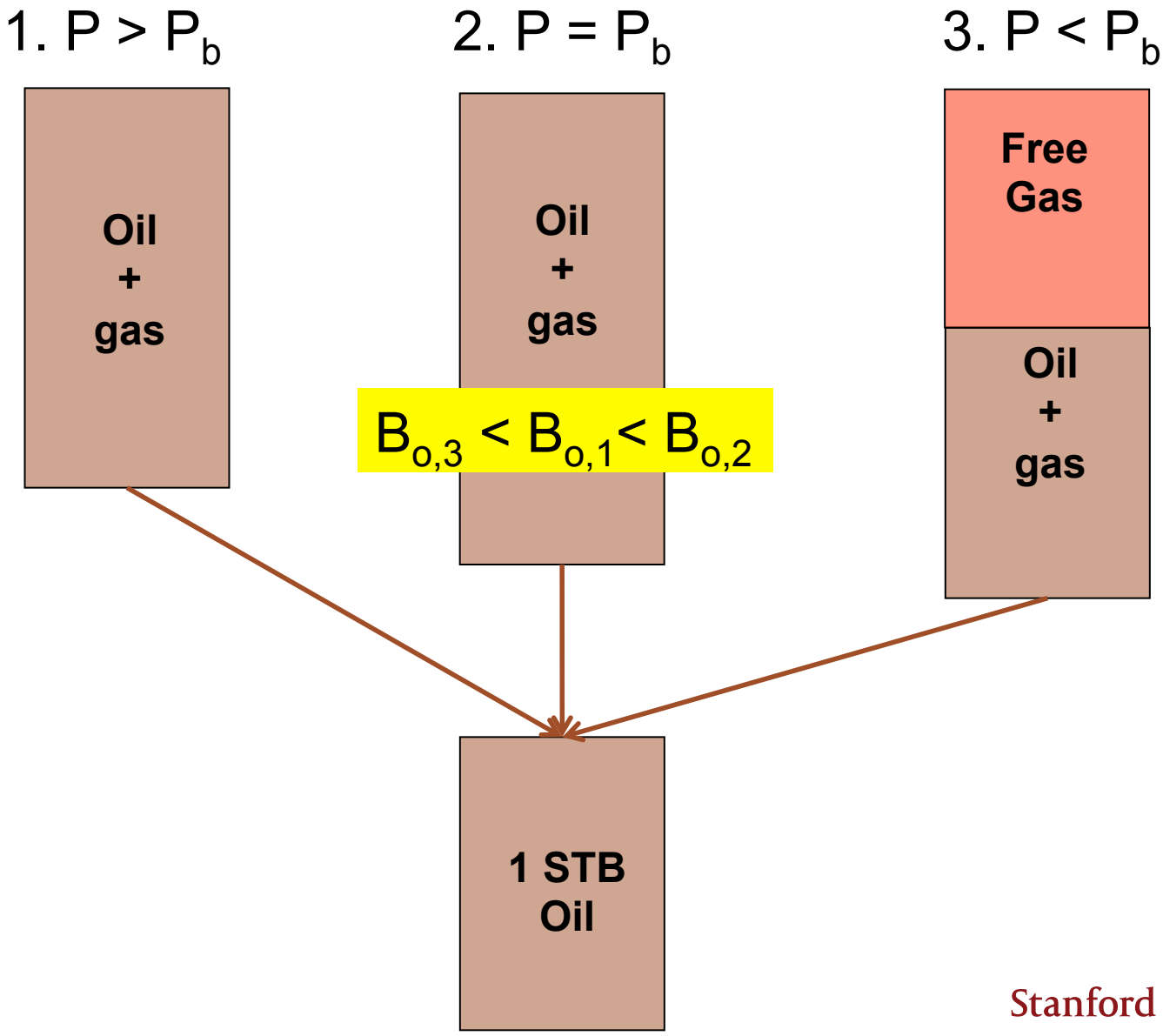
Units = RB/STB (unitless)

B_o depends on the composition of oil and gas

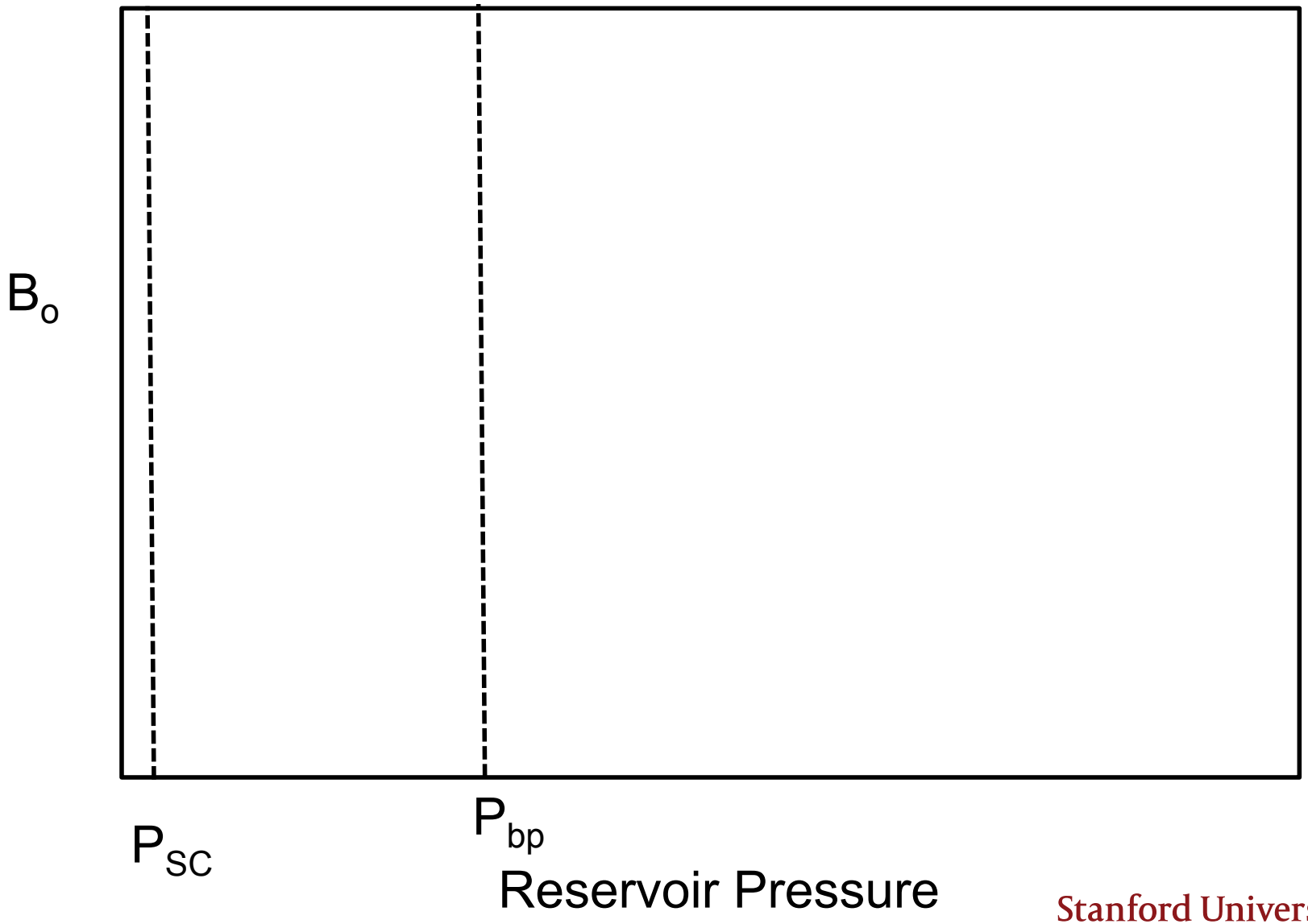
Oil Formation Volume Factor, B_o



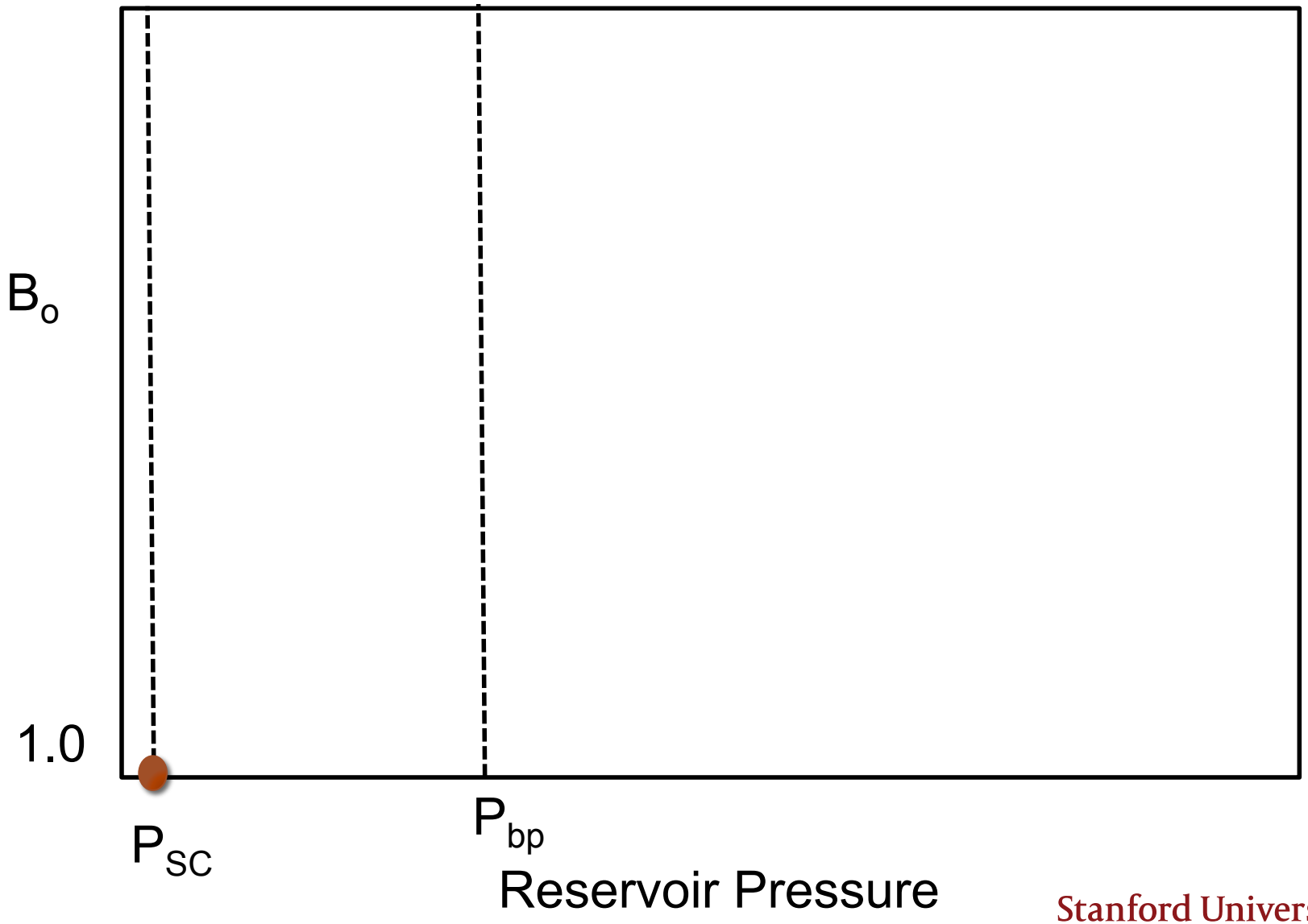
Oil Formation Volume Factor, B_o



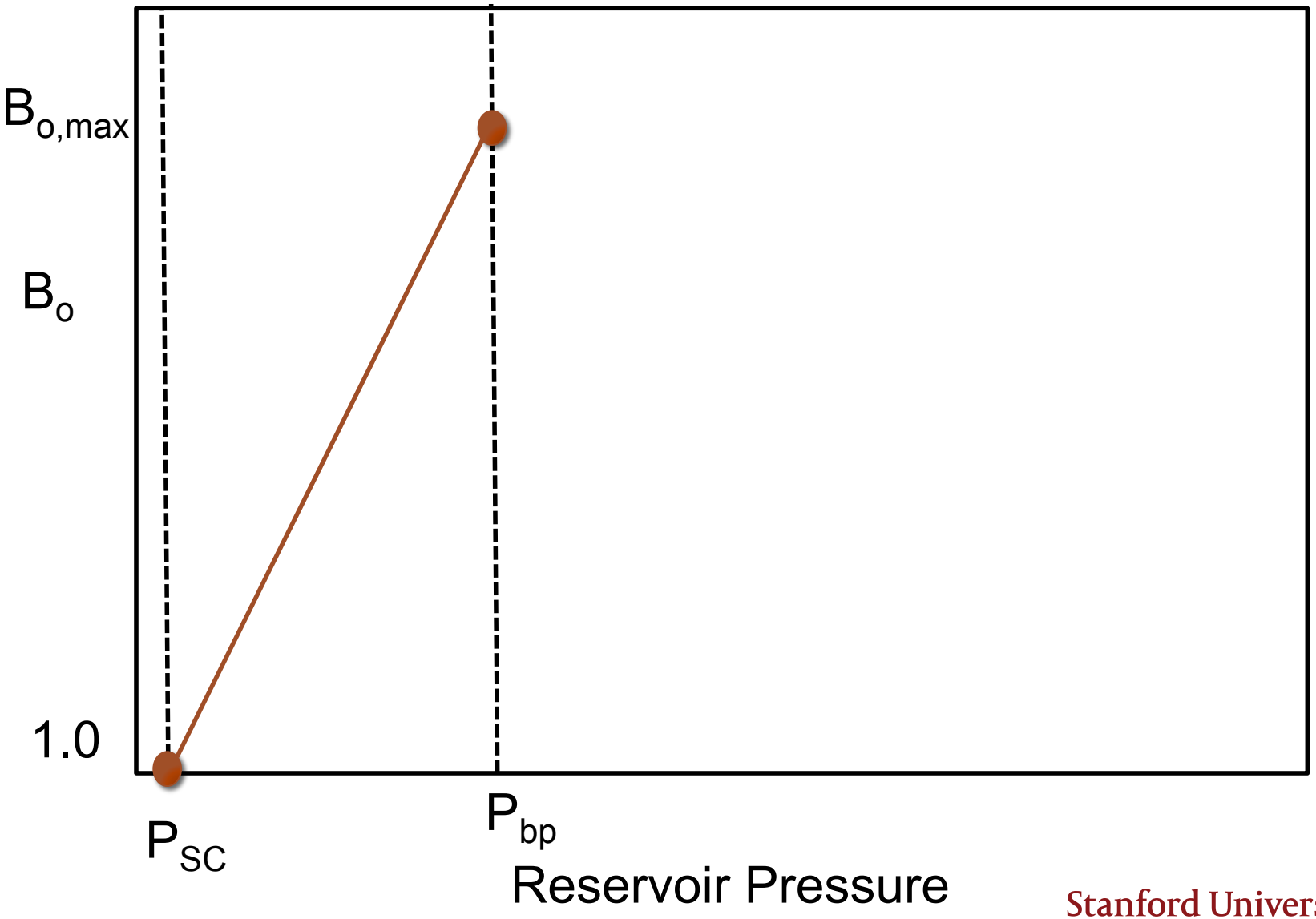
Oil Formation Volume Factor, B_o



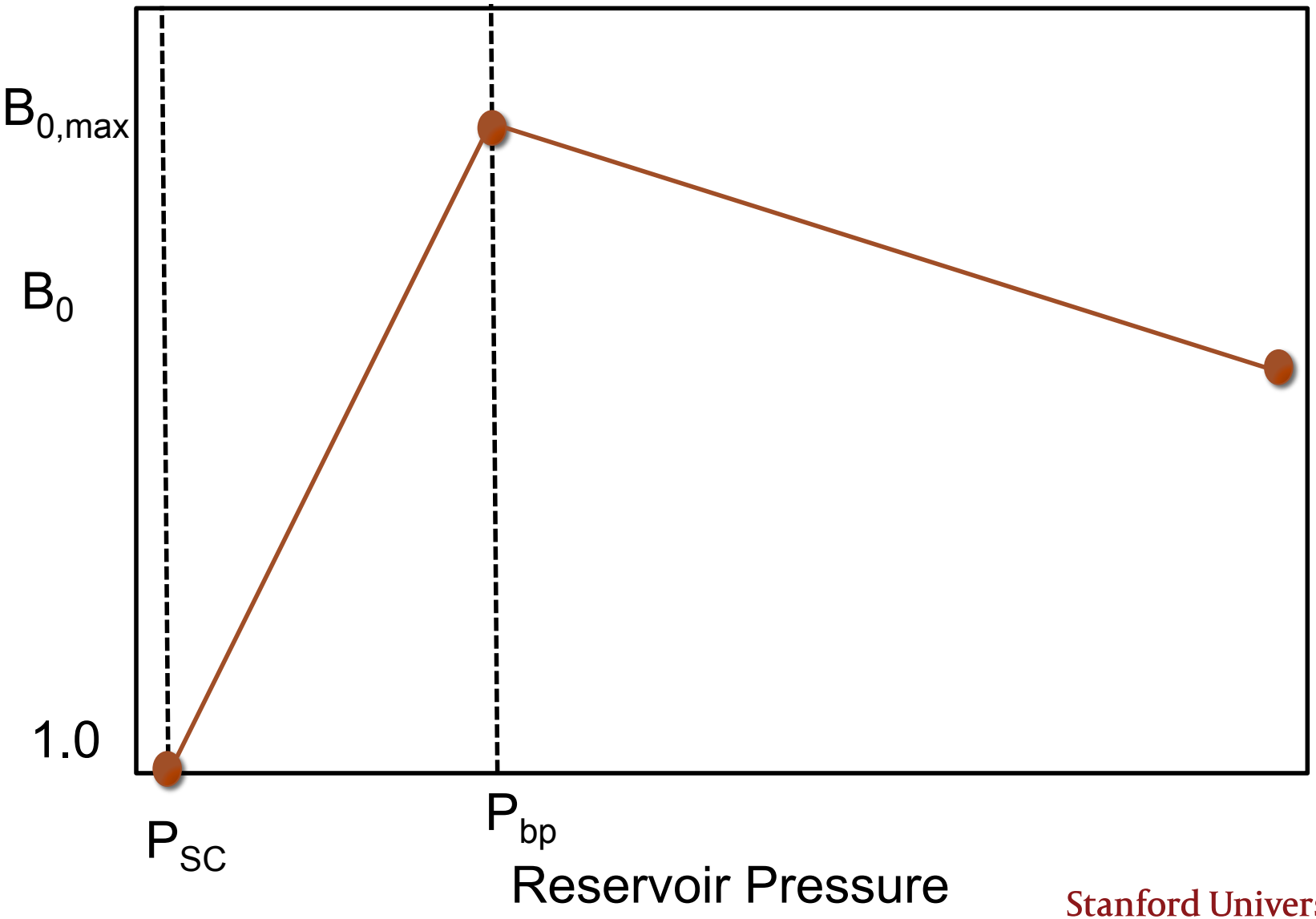
Oil Formation Volume Factor, B_o



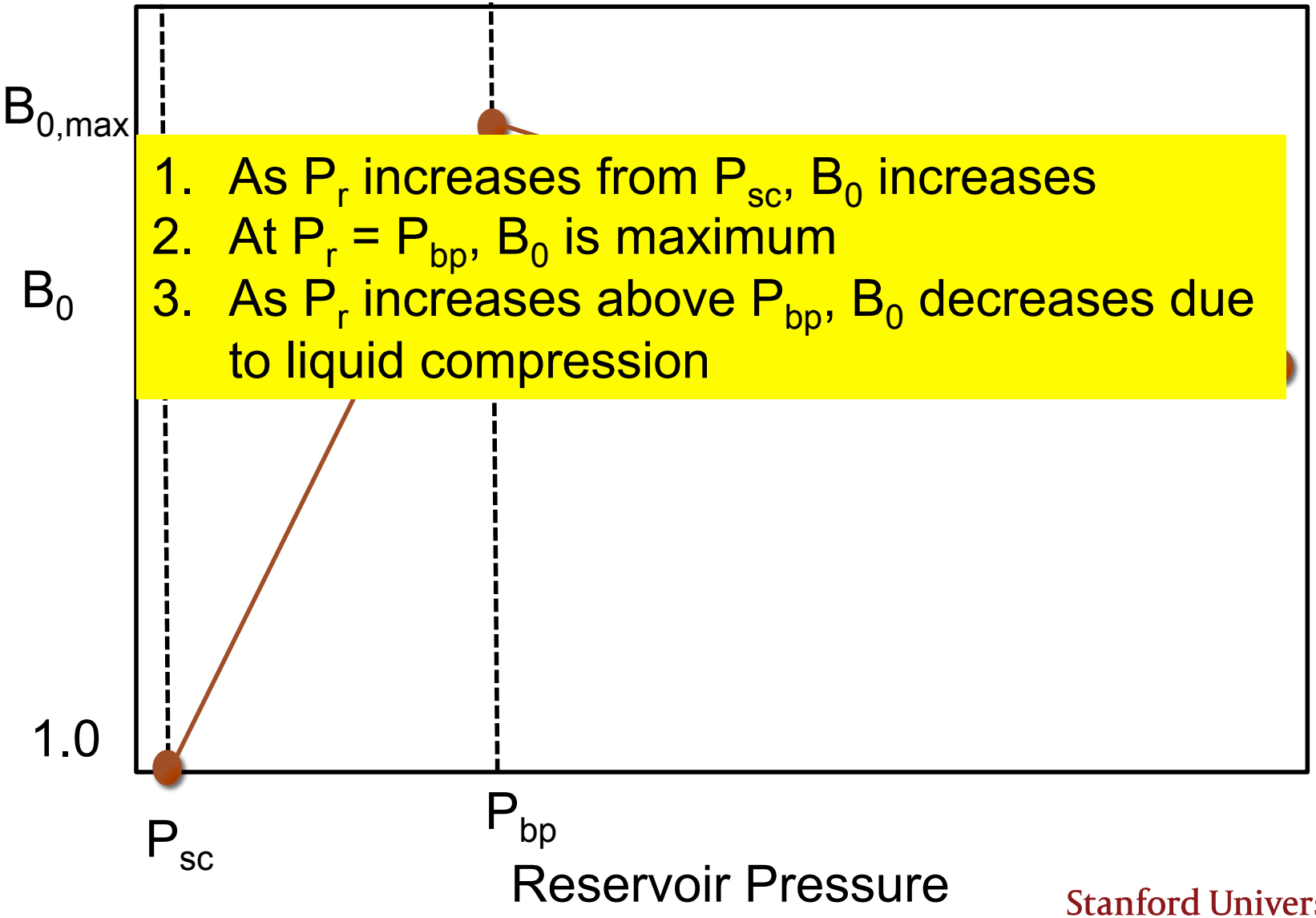
Oil Formation Volume Factor, B_o



Oil Formation Volume Factor, B_0

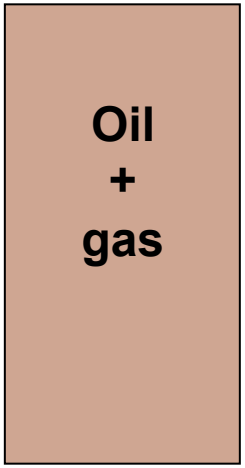


Oil Formation Volume Factor, B_0

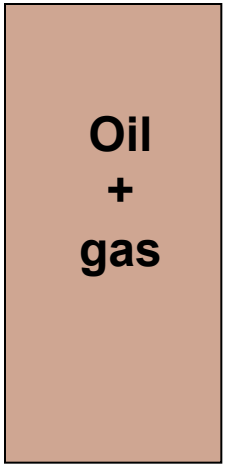


Thinking About B_o

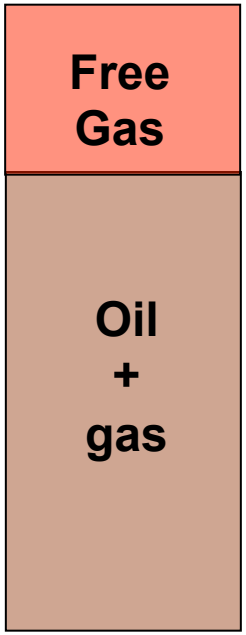
1. $P > P_b$



2. $P = P_b$



3. $P < P_b$

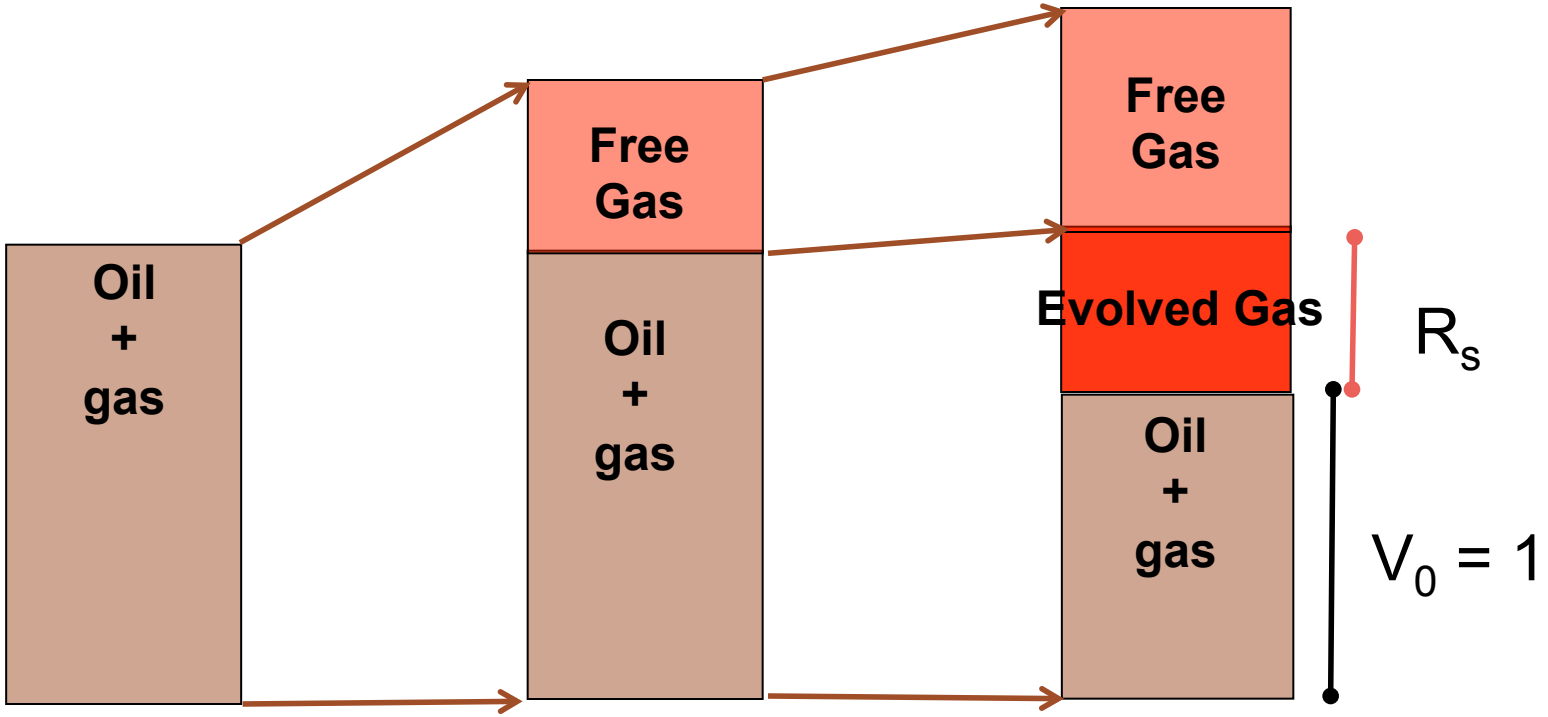


1. Which situation produces the most STB oil?
2. Which has the highest B_o?
3. How is B_o useful in characterizing reservoirs?

Solution Gas – Oil Ratio: Reservoir

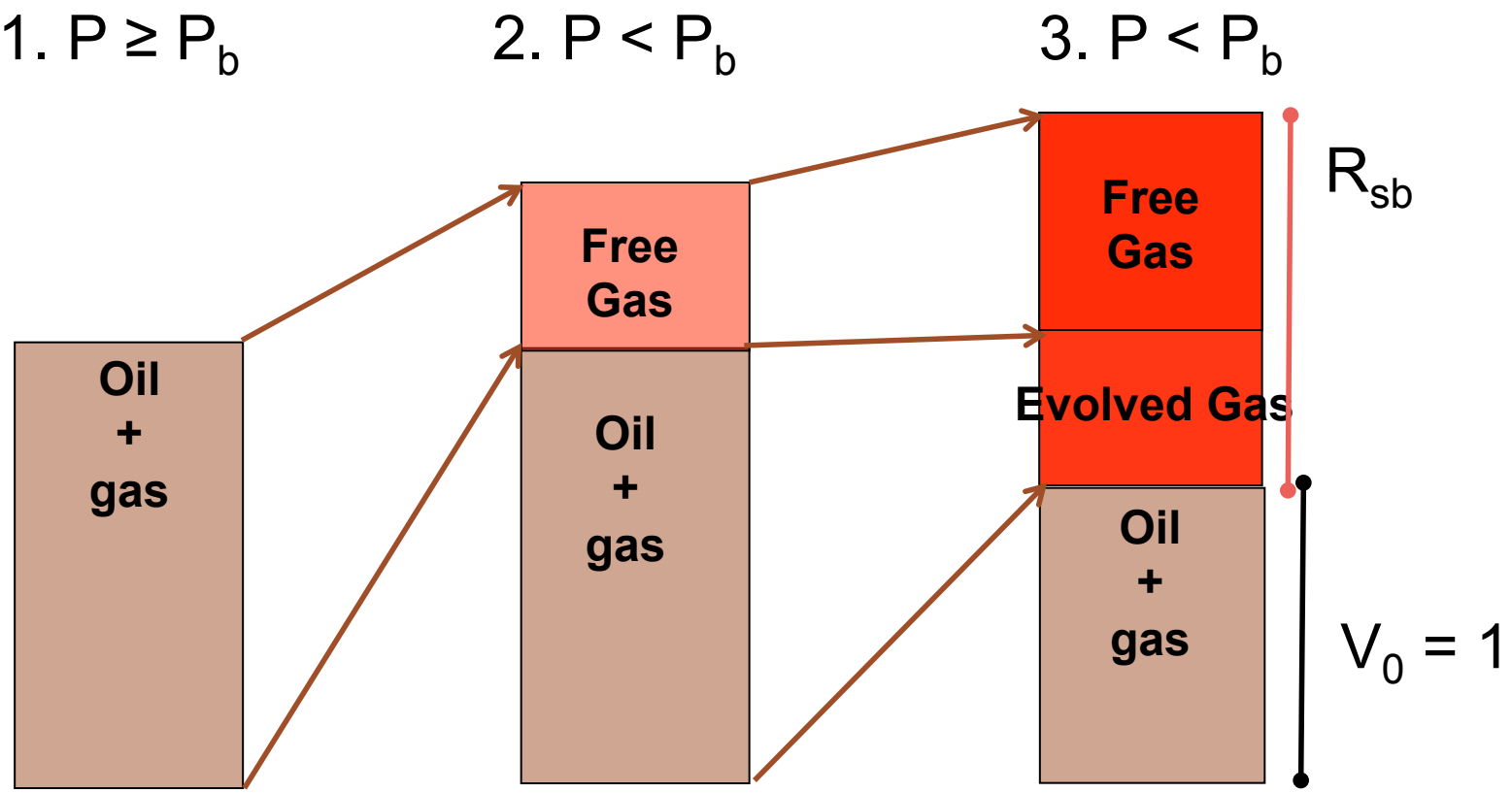
$$R_s = \frac{\text{Volume of Dissolved Gas @ RC (MCF/STB)}}{\text{Volume of Oil Entering Stock Barrel Tank @ SC}}$$

1. $P \geq P_b$ 2. $P < P_b$ 3. $P < P_b$



Solution Gas – Oil Ratio: Bubble Point

$$R_{sb} = \frac{\text{Volume of Dissolved Gas @ RC (MCF/STB)}}{\text{Volume of Oil Entering Stock Barrel Tank @ SC}}$$



Solution Gas – Oil Ratio, R_s and R_{sb}

Information R_s and R_{sb} provides:

How much gas is formed during production of one STB of oil at the surface?

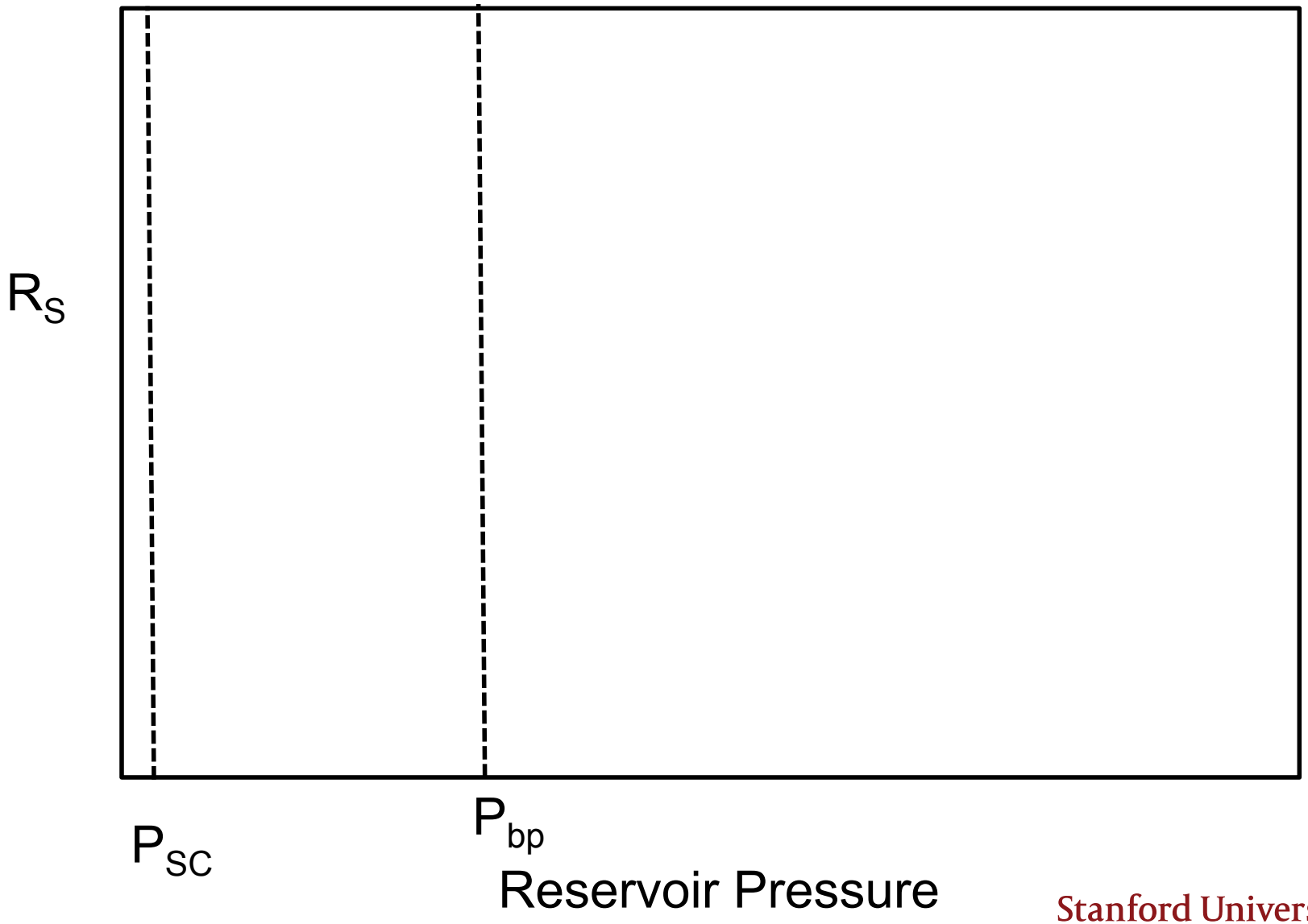
R_s depends on the reservoir pressure:

- **If $P < P_{bp}$ much of the gas component* is free in the reservoir, but some gas is dissolved in the oil**
- **If $P = P_{bp,}$ the maximum amount of gas possible is dissolved in the oil**
- **If $P > P_b$ the maximum amount of gas possible is dissolved in the oil and the oil is compressed**

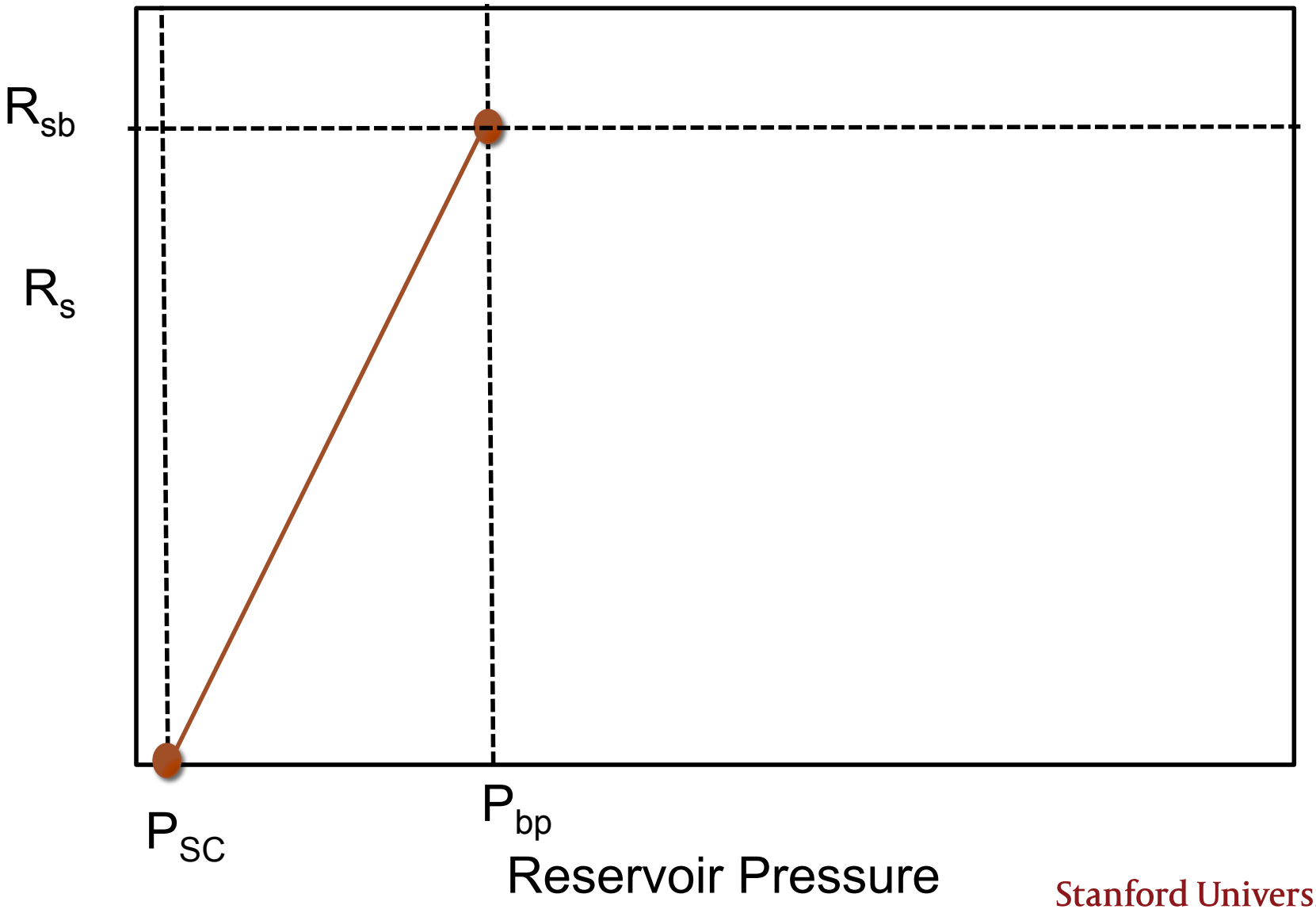
gas component refers to species that are gaseous at STP

R_s depends on the composition of oil and gas

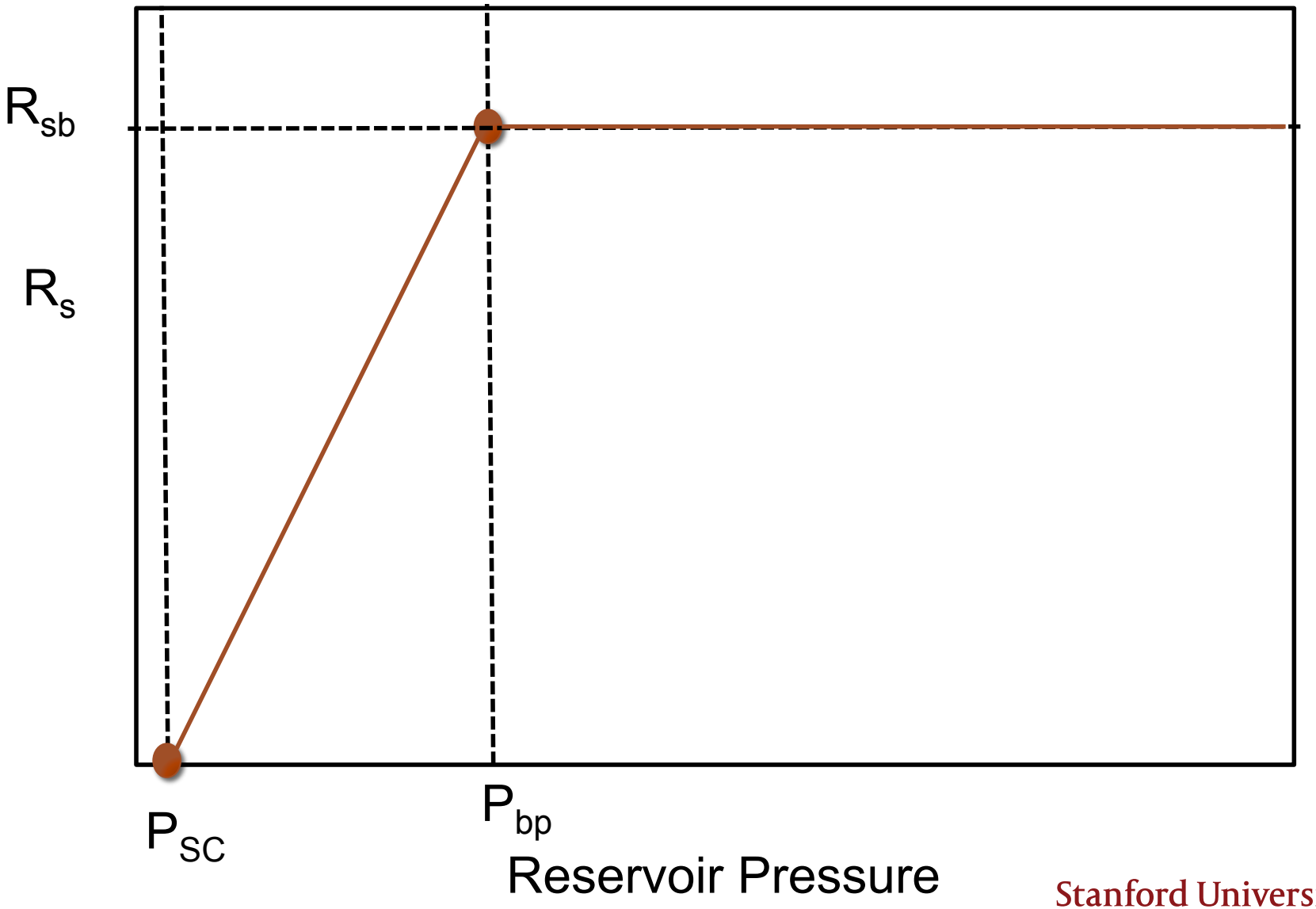
Solution Gas – Oil Ratio, R_s



Solution Gas – Oil Ratio, R_s

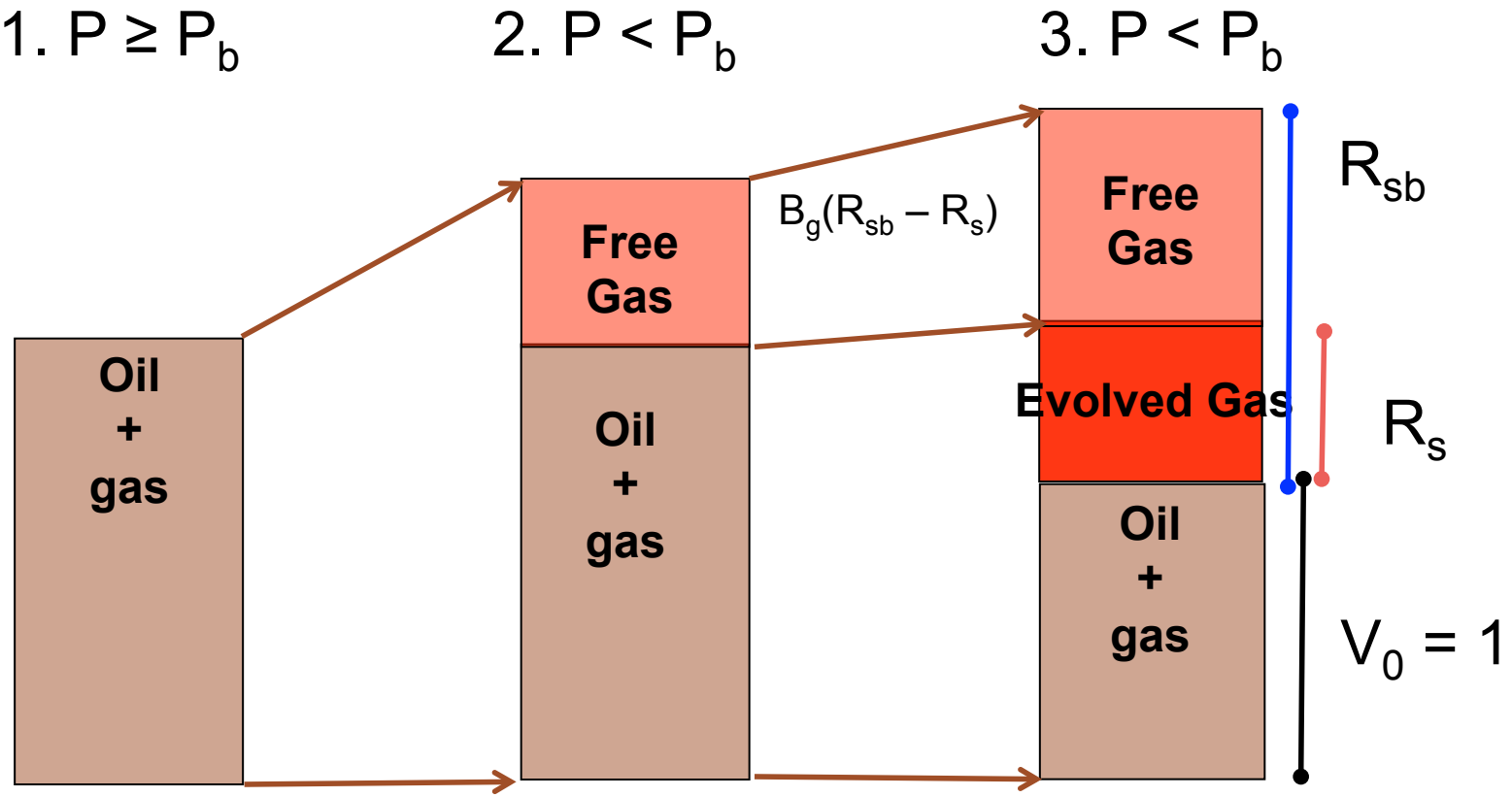


Solution Gas – Oil Ratio, R_s

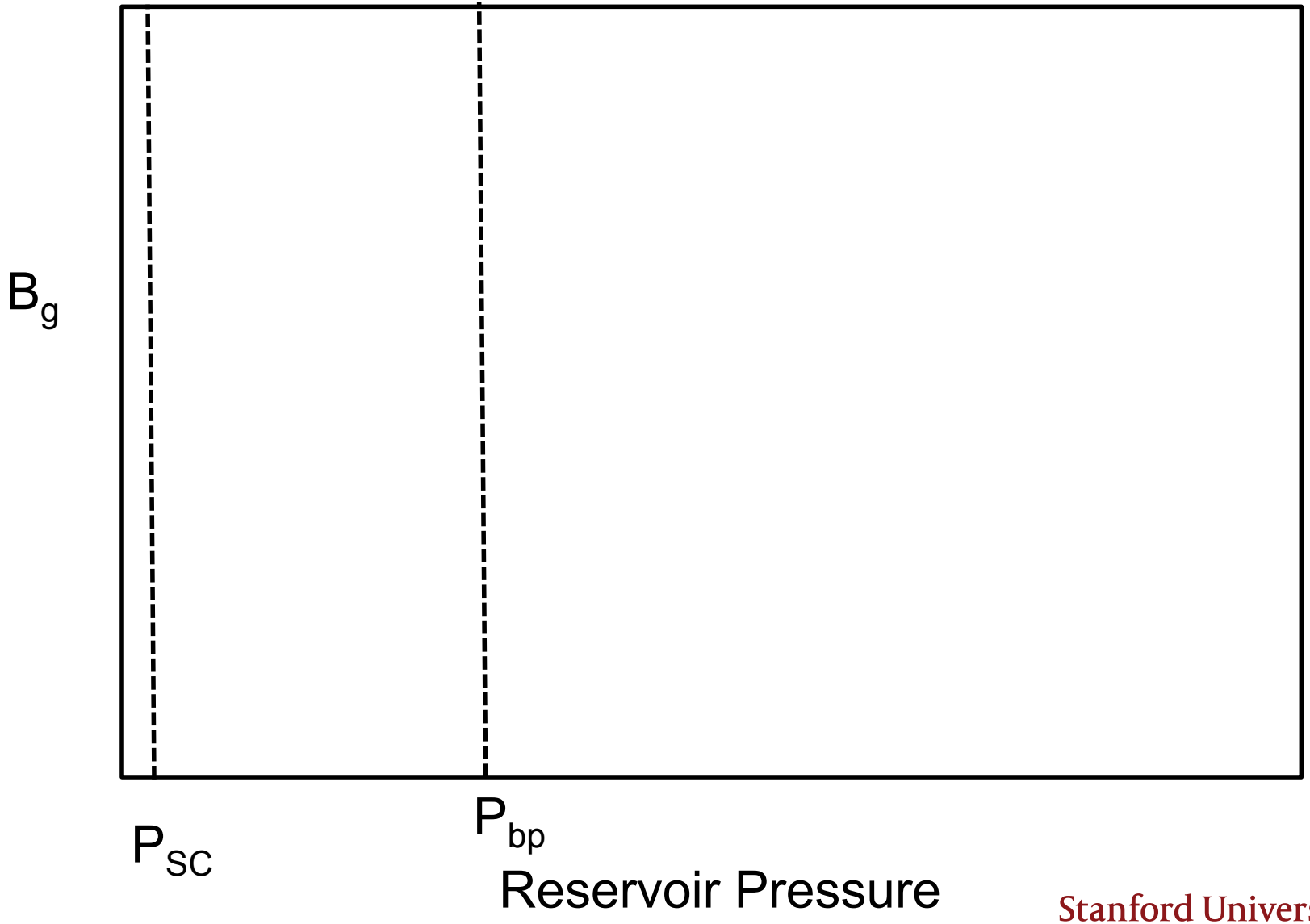


Gas Formation Volume Factor, B_g

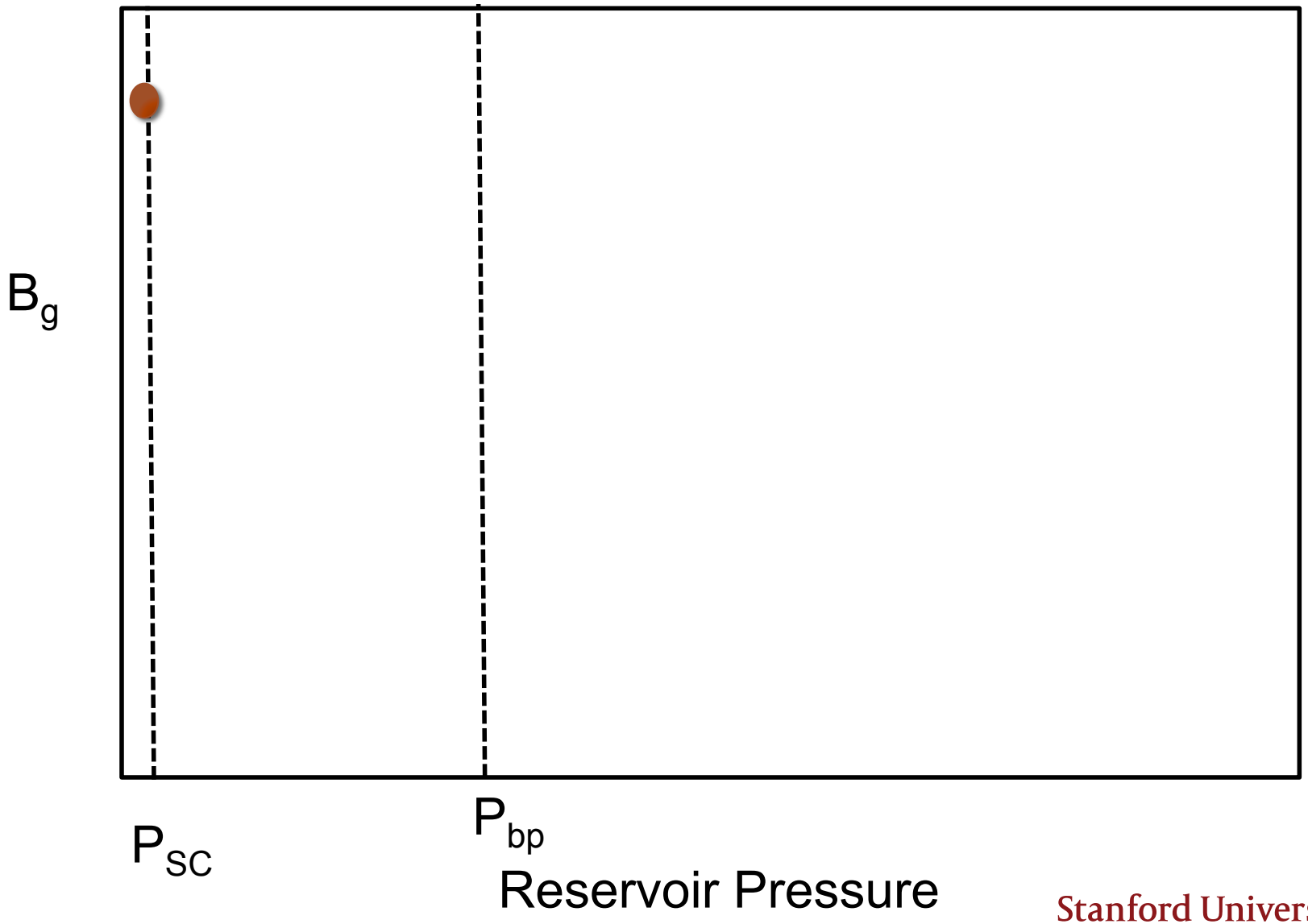
$$B_g = \frac{\text{Volume of Gas @ RC}}{\text{Volume of Gas @ SC}}$$



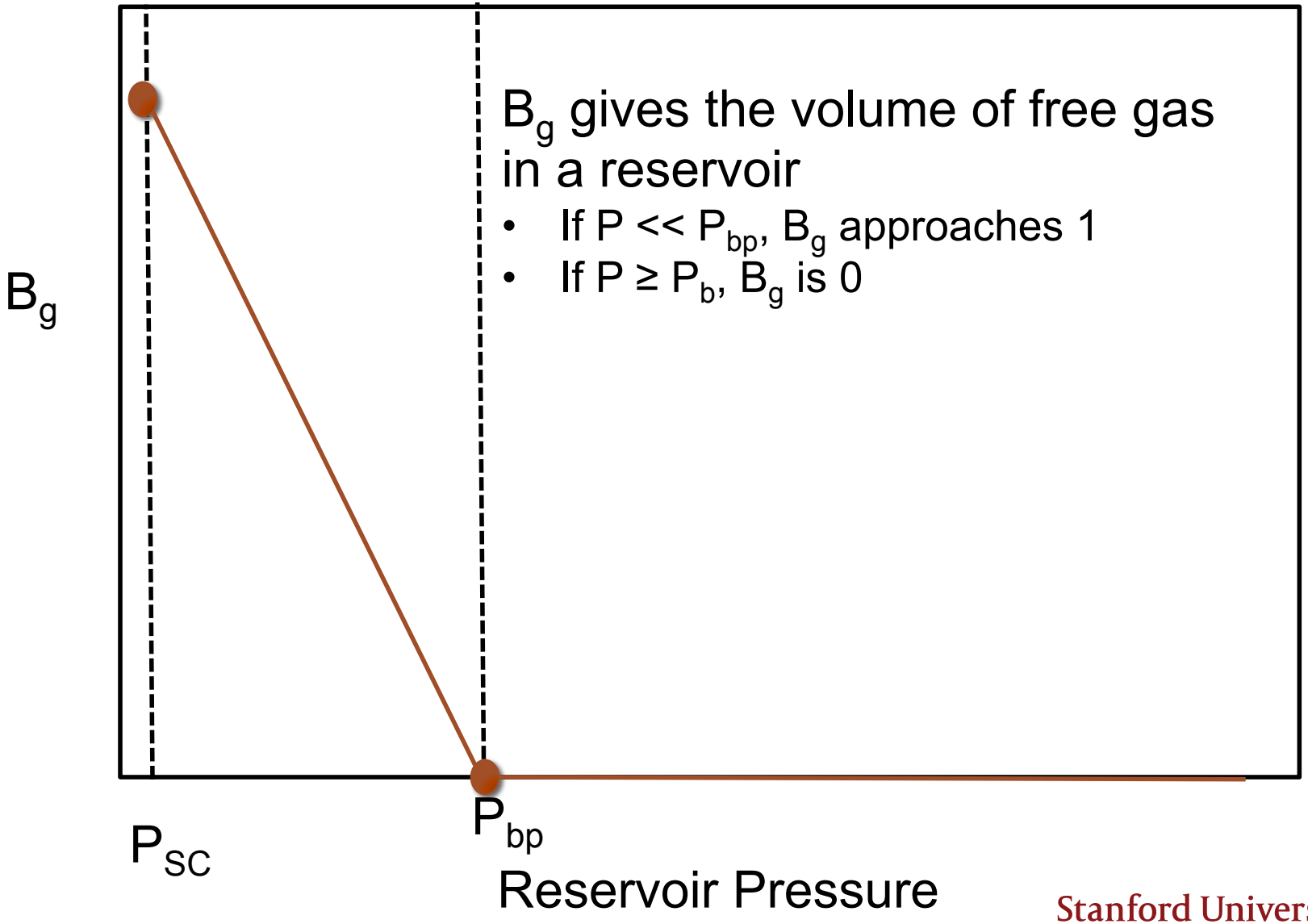
Gas Formation Volume Factor, B_g



Gas Formation Volume Factor, B_g



Gas Formation Volume Factor, B_g

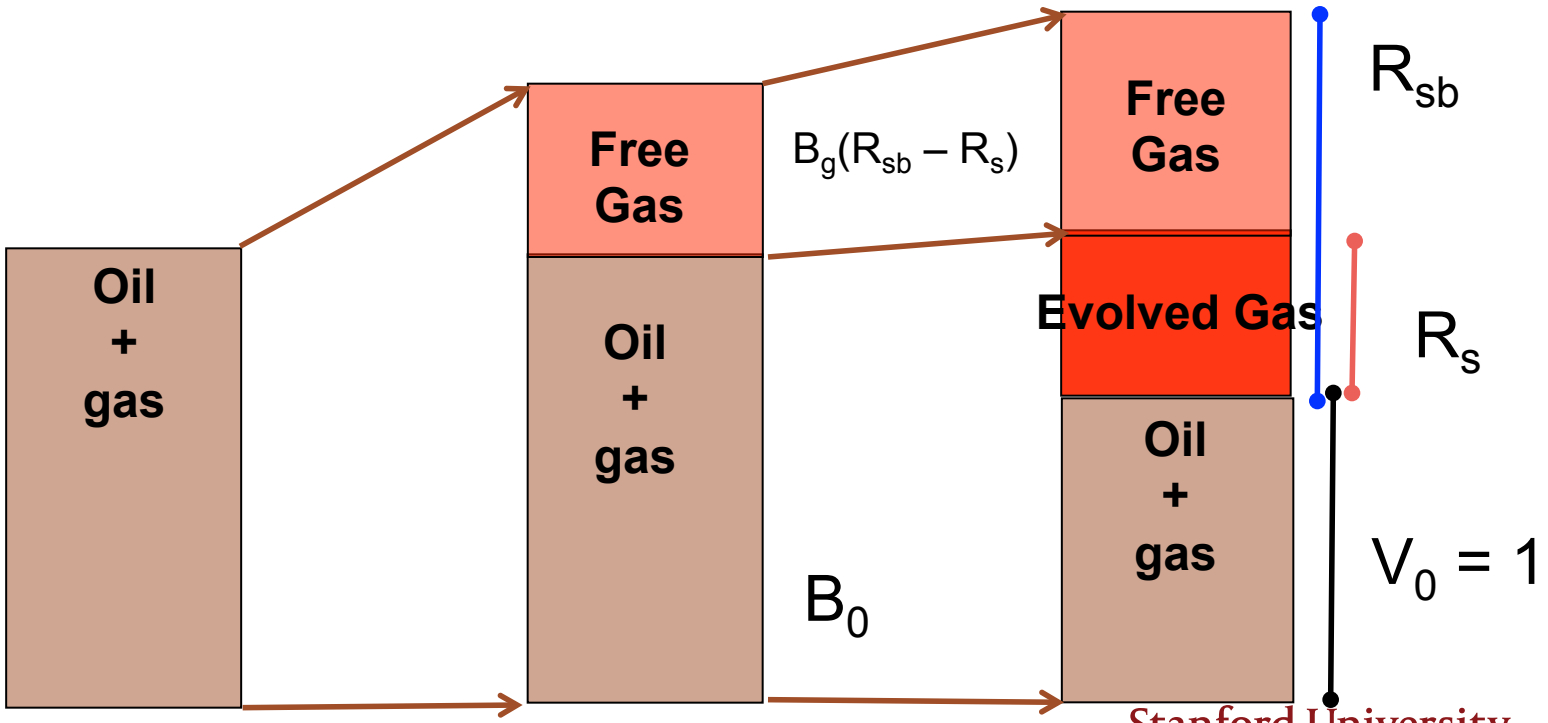


Total Formation Volume Factor, B_t

$$B_t = \frac{\text{Vol of oil + gas @ RC + Vol of free gas @ RC}}{\text{Volume of Oil @ SC}}$$

$$B_t = B_0 + B_g(R_{sb}-R_s)$$

1. $P \geq P_b$ 2. $P < P_b$ 3. $P < P_b$



Total Formation Volume Factor, B_t

Pressure (psig)	B_o (RB/STB)	R_s (SCF/STB)	B_g (RB/SCF)
5000	1.498	941	
4500	1.507	941	
4000	1.517	941	
3500	1.527	941	
3400	1.53	941	
3300	1.532	941	
3200	1.534	941	
3100	1.537	941	
3054	1.538	941	0.000866
2700	1.484	819	0.000974
2400	1.441	732	0.00109
2100	1.401	646	0.001252
1800	1.361	562	0.001475
1500	1.323	481	0.001795
1200	1.287	400	0.002285
900	1.252	321	0.003108
600	1.215	240	0.00476
300	1.168	137	0.009683

Phase Behavior of Reservoirs

Friday, we will study five types of reservoirs:

1. Black oil
2. Volatile oil
3. Retrograde gas
4. Wet gas
5. Dry gas